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Computer Generation and Classification of Music through Operations Research Methods

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This is a summary of the authors PhD thesis supervised by Kenneth Sörensen and defended on December 12th, 2014 at Universiteit Antwerpen. The thesis is written in English and is available from the author upon request at `dorien.herremans@gmail.com` and from `http://antor.uantwerpen.be`. This work deals with applying methods from operations research (OR) to the field of music.

The digital economy has grown tremendously over the last few years according to the Digital Agenda for Europe (DAE). Computer generated music is one of these emerging technologies that has a plethora of applications including game music, performance, interactive arts, stock music for advertising and videos, and background music. Music classification systems are also getting increasingly prominent in our daily lives, e.g. in the form of music recommendation systems and playlist suggestion systems. In this thesis, a range of topics are explored including dance hit prediction, structured music generation and composer classification.

In the first part of this research, different algorithms are developed that can *generate music* with an objective function based on *music theory rules*. A large set of rules is quantified from music theory and implemented as evaluation criteria for the generated music. Using this objective function, a variable neighbourhood search algorithm (VNS) and a genetic algorithm (GA) are developed and extensively tested. The VNS outperforms the GA and is able to efficiently generate counterpoint music, a type of 16th century classical music. The algorithm is first implemented for first-species counterpoint and later for fifth species, a more complex form of counterpoint that also includes a rhythmic aspect. The parameters of the algorithm are determined based on the results of a full factorial experiment. The resulting algorithm is implemented in `C++` and is available as an open source plugin for the popular music notation software Musescore (`http://antor.uantwerpen.be/optimuse`).

In the next part of the research, we break free from using a predefined objective function and move towards a *machine learned model* to evaluate the quality of generated pieces. Using machine learned models to capture a musical style allows us to work with a plenitude of styles and model aspects that might be

too abstract to be included in rules from music theory, thus allowing us to generate more complete music. It might even stimulate the discovery of new rules and thus expand existing music theory. Based on a large dataset of existing music, different classification models are built including support vector machines, logistic regression and decision tree models. The most efficient model reaches an accuracy of 86% and an AUC of 93% when classifying pieces between three composers (Bach, Beethoven and Haydn). The logistic regression model combined with the previously used counterpoint rules is integrated in the objective function of the VNS algorithm to allow the generation of counterpoint music with characteristics of a certain composer. The VNS is modified so that it can generate a continuous stream of new music containing characteristics of a certain composer. The interface contains three sliders, one for each composer, which allows the user to control the amount of influence of that particular composer in the generated music. The app is freely available in the Google Play Store (`https://play.google.com/store/apps/details?id=com.dh.fux2`).

The power of Markov models combined with multiple viewpoints is then explored to model a musical style. Due to the size of many datasets it is often only possible to get rich and reliable statistics for *low order* models. Music sampled by a low order Markov model, however, typically lacks a theme or a larger structure. Therefore, different novels ways of using Markov models to build quality assessment metrics which stimulate *long term coherence* are examined. All of the metric are implemented as the objective function of the VNS, which allows us to restrain the structure of a music through various hard and soft constraints. The results of generating music with the VNS using each of the different objective functions are evaluated in detail through an experiment with music for bagana, an Ethiopian lyre. We chose to work with music for bagana because it is such a simple form of music, on which the effect of the different metrics can easily been seen by an expert. Secondly, it has a very specific repetitive structure. A method is developed that allows the generation of music into this cyclic structure.

In the final part of this research, the power of machine learning on audio data is put to the test and a system for *dance hit prediction* is built. In 2011 record companies invested a total of 4.5 billion in new talent worldwide. Gaining insight into what actually makes a *hit* song would provide tremendous benefits for the music industry. In this research we tackle this question by focussing on the *dance* hit song classification problem. A database of dance hit songs from 1985 until 2013 is built, including basic musical features, as well as more advanced features suggested by the authors that capture a temporal aspect. A number of different classifiers, including support vector machines, logistic regression and rule based models, are used to build and test dance hit prediction models. The resulting best model has a good performance when predicting whether a song is a "top 10" dance hit versus a lower listed position. The model correctly identifies 83% of the songs in the test set as hits. The model is implemented as an online tool where users can upload their mp3s and see their hit potential (`http://antor.uantwerpen.be/dance`).